Patterning Method of IPMC Actuator Using a Milling Machining

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Abstract. A simple and low-cost pattering method is proposed for arbitrary undulatory motion of IPMC actuator. A commercial milling machine is used to provide desired pattern width and depth on surfaces of IPMC actuator. The copper tape is then used to connect electricity to electrode of patterned surfaces. The 2-segment patterned IPMC actuators are fabricated by combining electroless plating and milling machining which can provide precise patterning and control thickness of Platinum electrode layer. It is experimentally confirmed that the proposed patterned IPMC actuator produces undulatory motion as expected. The suggested method can easily be implemented into the IPMC actuator for various applications.

Introduction

Recently an active polymer actuator has drawn researchers’ attention due to its light and thin properties. The active polymer actuator can easily be manufactured in various forms and it can generate a large displacement at low voltage, which is difficult to realize using existing traditional actuators such as electric motors and piezoelectric actuators.

The Ionic Polymer Metal Composite (IPMC), which is fabricated by using platinum electroless plating Nafion polymer substances, is also widely used for actuators. The advantages of the IPMC actuator are large deformation, low power consumption, lightweight, biological compatibility, and bio-mimetic properties. Thus, IPMC actuators have been applied to various applications in robotic, medical and military fields.

IPMC consists of Nafion where water can move and platinum electrode on both surfaces of Nafion as shown in Fig. 1 [1]. When a voltage is applied to the electrode of IPMC, the magnetic field is generated and the molecules of water move to the cathode together with the sodium ions(cations). At this time, SO3- groups(anion) is fixed and partial volume change occurs due to imbalance in the volume of the water molecules. At the cathode side the polymer stretches due to abundant cations and the water molecules whereas compression occurs at the other side. As a result, the IPMC actuator is bent. As the input voltage is applied in reverse, the corresponding bending direction of the IPMC actuator is changed.

Typically the IPMC actuator is fabricated by using a single actuator changed the direction in which a voltage is applied. For applications like biomimetic robots, the uses of IPMC actuators provide disadvantages in force and displacement and difficulty in connecting electrodes. To overcome these drawbacks, undulatory motion of the IPMC actuator is suggested [2, 3]

To make undulatory motion, it is necessary that the patterned electrode induce the different electric power to the each part of the IPMC actuator. There are two method to make the patterned electrode. The first method is to make the desired pattern during the fabrication process of the IPMC actuator. The second method is to remove the electrode to make the desired patterned. The first method uses the make of the desired pattern [4-6]. In this method it is however difficult to make the sophisticated patterned and more expensive. The second method removes the electrode physically. Laser cutting and micro cutting is suggested in [7, 8]. However, the equipment for laser cutting and micro cutting is expensive.
Hence, a simple and efficient method to make undulatory motion of the IPMC actuator with easy power connection is suggested in this paper.

![Fig. 1. Actuation principle of IPCM](image)

**Manufacturing the Patterned IPMC Actuator**

The electroless plating method with platinum as an electrode is used to prepare the IPMC actuator. The Platinum electrode cover the both side of Nafion NE-1110 through the electroless plating method. Generally the IPMC actuator can bend in water easily whereas it is stiff in air. To make motion in air, H+ ion is changed to Li+ ion and conduct ionic liquid replacement. The fabrication procedure is shown in Fig. 2. The fabricated IPMC actuator is cut by a razor to make desired shape. The thickness of the platinum electrode is 20 µm through the 4 times of electroless plating. The SEM image is shown in Fig. 3.

![Fig. 2. Fabrication procedure of the IPMC actuator](image)
The plated platinum electrode is a metal that can be removed by machining. It is possible to use a general milling machine to move with 1 µm resolution. The diameter of a milling tool decides the width of a removed electrode. The patterned IPMC actuator is thus made by using a general milling machine with 1 mm flat end mill. The cross-section image of the removed electrode is shown in Fig. 4. This method is cost effective.

Connection of the Patterned Electrode

Methods that use micro-soldering [3] and the through hole filled conductive material [6] were suggested to induce the different electric power to the each part of the IPMC actuator. These methods are complicated and can damage the IPMC actuator. To avoid physical damage and induce the electric power easily, the copper tape is used. The wire is soldered on copper tape instead of the surface of the platinum electrode so there is no damage to the IPMC actuator. The micro weld effect occurs between the platinum electrode and the copper tape. The wires are cross-connected as shown in Fig. 5. The Prototype of the patterned IPMC actuator is shown in Fig. 6. The size of prototype is 5mm wide by 24 mm long and each segment is separated by a 1-mm groove of 10 mm long.
Experimental Result

The experimental setup is shown in Fig. 7. The power op-amp (L272) is used to induce the 2 V voltage and the Laser displacement sensor (Kyence LB-08) is used to measure bending displacements of the IPMC actuator. The 2-segmented patterned IPMC actuator produces the undulatory motion at 2 V input. The displacement of end tip is 0.3 mm.

The 2-segmented patterned IPMC actuator produces different bending at 10 mm, position of the patterned groove as found in the experimental result, Fig. 8.

Conclusion

In this research a simple and cost-effective patterned electrode method is presented to make the various bending motion the IPMC actuator. It is possible to make the desired patterned electrode using a general milling machine and connect electrodes each other easily by using copper tape. The prototype of the 2-segmented patterned IPMC actuator is fabricated and experimented. It is confirmed experimentally that the proposed patterned IPMC actuator provides undulatory motion. The suggested method can easily be implemented into the IPMC actuator for various applications.
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References


